Patent Application of

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For

TITLE: MOTION VIDEO CHOLESTERIC DISPLAYS

BACKGROUND OF THE INVENTION

Cholesteric liquid crystal displays are characterized by the fact that the pictures stay on the display even if the driving voltage is disconnected. The bistability and multistability also ensure a completely flicker-free static display and have the possibility of infinite multiplexing to create giant displays and / or ultra-high resolution displays. In cholesteric liquid crystals, the molecules are oriented in helices with a periodicity characteristic of material. In the planar texture, the axis of this helix is perpendicular to the display plane. Light with a wavelength matching the pitch of the helix is reflected and the display appears bright. If an AC-voltage is applied, the structure of the liquid crystals changes from planar to focal conic texture. The focal-conic texture is predominately characterized by its highly diffused light scattering appearance caused by a distribution of small, birefringence domains, at the boundary between those domains the refractive index is abruptly changed. This texture has no single optic axis. The focal-conic texture is typically milky-white (i.e., white light scattering). Both planar texture and focal-conic

texture can coexist in the same panel or entity. This is a very important property for display applications, whereby the gray scale can be realized.

However, current cholesteric displays are limited in low frame speed, storage type devices. Since very beginning, one has dreamed to achieve a good moving picture by using variety of methodologies, but it seems to conclude that cholesteric display with passive driving is almost impossible to realize a true video rate display which is over 30 frames per second.

In the article of "Storage-Type Liquid Crystal Matrix Display" (SID 79 Digest, p.114-115) Tani proposes a driving method for the ChLCD. The display adopts a vertical alignment treatment and the liquid crystal pixel can be driven from stable planar texture to stable focal conic texture or from stable focal-conic texture to stable planar texture depending on the pre-designed waveform. The hysteresis behavior during the phase transition of nematic-cholesteric liquid crystal under an applied electric field can be used for bistable display for high multiplex application. The stability of the hysteresis effect was defined as the width of hysteresis. That is the difference between the voltage, which gives 50% transmittance in cholesteric-to-nematic phase transition and the voltage, which gives 90% in nematic-to-choloesteric phase transition. This behavior has been used for projection display where a large information content is required.

It is well known that only dielectrically positive cholesteric LC cells with homeotropic boundary conditions have an electro-optical hysteresis effect. The LC cell in its quiescent state assumes an almost transparent spiral texture. It alters to scattering fan-shaped texture upon voltage application, and transforms at threshold voltage to a homeotropic nematic texture as a result of the field-induced phase transition. The cell remains in a metastable homeotropic texture for a rather long time, when the voltage is lowered from V_1 ($V_1 > V_H$) to V_2 ($V_H > V_2 > V_H' \cong V_H/2$). When the applied voltage is switched off from V_1 (or V_2) to zero, a rapid relaxation from the transparent nematic texture H (or H') to the initial quiescent texture. Light transmission during the rapid passage exhibits a hump G^* before it reaches minimum at state G'. The state G^* was found to be a transient planar texture, and the time interval of the transition from texture H (or H') to texture G^* is interpreted to be the nematic-chloesteric transition time, τ_{NC}. If voltage V_2 is applied after a time interval, such that $t_0 > \tau_{NC}$, a scattering texture F' is formed,

which transforms to stored scattering texture F_0 after the voltage removal. Thus, scattering texture F_0 and transparent texture S can be selected by either putting $t_0 > \tau_{NC}$ or $t_0 = 0$. This is the basic principle of this storage-type LCD. In the case of a matrix display, the number of scanning lines is limited by the ratio T/t_0. T and τ_{NC} values are usually several seconds and several milliseconds, respectively. Therefore, the ratio T/t_0 can be as high as several hundred.

The matrix display panel described is driven by a line-at-a-time addressing. The addressing process is proceeded by the pre-excitation process that the higher voltages V_1 larger than V_H are applied to all matrix elements. This pre-excitation process corresponds to the initial stage where the liquid crystal is made homeotropic. In the matrix display, scanning signals are applied to the row electrodes and data signals are applied to the column electrodes. $V_{(0)}$ and $V_{(\pi)}$ are ac pulses, which have the same height and 180^0 phase difference. The pulse heights of $V_{(0)}$ and $V_{(\pi)}$ are less than V_H. The voltage of scanning signals is 0 for non-addressed lines, and $V_{(\pi)}$ for an addressed line. The voltage of data signals is $V_{(0)}$ for non-addressed lines, and $V_{(\pi)}$ for an addressed line. Therefore, the voltage applied to the addressed element is 0, and V or 2V is applied to the other elements. After this addressing process, the voltage for all elements are removed.

Through a total writing process, the applied voltage changes in ways as $V_1 \rightarrow V \rightarrow 0 \rightarrow V \rightarrow 0$ or $V_1 \rightarrow 0 \rightarrow V \rightarrow 0$ at the addressed element, which makes the liquid crystal the stored light scattering state. On the other hand, the voltage change at the on-addressed element is $V_1 \rightarrow V \rightarrow 2V \rightarrow V \rightarrow 0$ or $V_1 \rightarrow 2V \rightarrow V \rightarrow 0$, which makes the LC the quiescent transparent state. The existence of the 2V pulse has on influence on the metastable homeotropic state H' since 2V is larger than V_H. In this way, the matrix panel forms the stored image. The V_2 range giving successful display performance is given by the inequality $0.6 < V/V_H < 0.9$, which gives a variation allowance in LC layer thickness d.

The storage type display has the advantages of long storage time, which makes refreshing or updating of the information on the display unnecessary. However the scanning speed is relatively slow and each line needs 8 ms to address the pixels and the information can not display till the whole frame scanning is accomplished. The power

consumption is high because of the two phase change voltages to the non-selection pixel and multi driving pulse sequence are over the phase change (untwist threshold) voltage.

USP 5,748,277 divides the information writing into three stages, i.e., preparation, selection and evolution. In the first preparation phase, a pulse or series of pulses causes the liquid crystal within the picture element to align in homeotropic texture and the display looks dark. The second stage is named selection step, during which the voltage added to the liquid crystal within the picture element are chosen so that the final optical state of the pixel will be either focal conic or twisted planar. In practice the voltage is chosen to either maintain the homeotropic texture or reduced enough to initiate a transition to the transient twisted planar texture. The third stage is evolution step, during which the liquid crystal selected to transform into the transient twisted planar texture during the selection step now evolves in a focal conic texture and the liquid crystal selected to remain in the homeotropic texture during the selection phase continues in the homeotropic texture. After evolution stage, there comes actually display stage where the voltage is taken to near zero or removed entirely from the pixel. The liquid crystal domains that are in the focal conic texture remain in the focal conic texture and those in the homeotropic texture transform into a stable light reflecting planar texture. The reported addressing time was reduced to 1 ms/line.

In the article of "High-Speed Dynamic Drive Scheme for Bistable Reflective Cholesteric Displays" (SID 97 Digest, p.97-100) Zhu proposes a five-phase driving method for the ChLCD, which is composed of five phases: preparation, post-preparation, selection, post-selection, and evolution. The state of the material after addressing depends only on the voltage in the selection phase that is around 50 μs long. The voltages in other phases are fixed at appropriate value and the drive waveform is implemented using a pipline algorithm. Using this drive scheme, it is able to update a 1000 line cholesteric display in approximately 0.05 seconds. However, video rate display is still impracticable. The fundamental problem is that the relaxation from the transient planar texture to the intrinsic stable planar texture will take about 200 ms, too long for a video rate display. Although it can be driven a frame as fast as 50 ms, the display does not relax completely to the planar texture during this time, and consequently the display had a very low brightness.

USP 5,661,533 teaches a method to speed up the relaxation time from field-induced-nematic texture to planar texture by dope a surfactant to liquid crystal material. It was realized that the response time has been reduced from 150 ms to 150 μs. The problem with the system was that the surfactant has high conductivity and the liquid crystal formula is not stable and reproducible. The video speed display with good performances has not been reported since the invention of the surfactant-liquid crystal system.

SUMMARY OF THE INVENTION

It is the primary object of this invention to realize a motion video cholesteric display with frame rate at least 30 frame per second.

It is another object of this invention to eliminate the slow relaxation process, i.e., from field-induced nematic texture to cholesteric planar texture. Instead, the field-induced nematic texture is devised as one of the optical state during the motion video display, whereby the field-induced nematic texture or homeotropic texture takes on a high transparency in optical "ON" state.

It is a further object of this invention to utilize the fast relaxation process, i.e., from field-induced nematic texture to cholesteric focal conic texture via transient planar texture. What is different from the prior art is that the motion video display takes the advantage of the fast-response focal conic texture, as the optical "OFF" state.

It is again another object of this invention to devise a driving scheme for a passive multiplexed motion video display. The driving scheme creates a special waveform to ensure a field-maintaining bitability during the motion video display, and a field-free bistability during the motionless information display. A narrow pulse planted in the "hole" shaped waveform will be able to drive the display to the optical "ON" state, while the "hole" shaped waveform itself driving the display to the optical "OFF" state. After erasing at least one portion of a frame, there comes an incremental line-to-line addressing waveform at the speed of 30-60 microsecond per line.

It is a still further object of this invention to create a display structure that takes the best advantage of the cholesteric intrinsic polarization and depolarization properties, thus produces black-and-white display and, furthermore, full color display. Compared with the

traditional cholesteric display where the planar and focal conic textures are designated as the optical "ON" and "OFF" states, those skills of the art deliver even higher display performances, such as multi-gray scale, high brightness, high contrast ratio and wide viewing angle.

It is additional object of this invention to render the display dual working functions. During the **motion** video display, the frame response is achieved by a video rate driving scheme. During the **motionless** information display, the display device will automatically convert to its field-free bistable mode, and further remain its long-time memory with zero power consumption. In one word, the present invention delivers a display with a property that it makes the display not only a TV or a computer monitor dynamically, but also a permanent picture or a print statically.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates schematic sectional display structures and configuration working in the motion video mode and motionless storage mode.

FIG. 2 illustrates an electro-optical curve of a cholesteric liquid crystal display.

FIG. 3 illustrates a schematic optic "OFF" waveform and focal conic relaxation of the first display scanning line.

FIG. 4 illustrates a schematic optic "ON" waveform and optical response of the first scanning line.

FIG. 5 illustrates a schematic optic "OFF" waveform and focal conic relaxation of the "m" scanning line; and also an optic "ON" waveform and optical response of the "m" scanning line.

FIG. 6 illustrates a schematic inter-frame waveform and optical response.

FIG. 7 illustrates a schematic erasing and addressing driving waveform for the video rate cholesteric display.

FIG. 8 illustrates a schematic driving waveform with partial erasing and addressing capability and gray-scale display capability.

DETAILED DESCRIPTION

Referring first to FIG. 1, illustrated is a reflective black-and-white cholesteric display structure. It consists of a display cell **110**, two circular polarizers (CPs) **120**, **130**, and a metal reflector **140**. The cell **110** is a basic structure of liquid crystal display, where a liquid crystal material with controllable homeotropic texture **114**, controllable focal conic texture **115** and controllable planar texture **116** are sandwiched between two patterned conductive substrates **111**, **112** (either glass or plastic) and isolated by a polymeric ring. The cell gap, which is predetermined by a spacer material, micro-balls or bars, is in the range of 1 to 10 micrometers. A thin polymer layer may be coated onto the inside of surfaces of the substrates to align the liquid crystal molecules in a specific way. An electronic waveform **160** needs to connect to the conductive lead **113** of the cell. In the case of multicolor or full color display the concept of cell will be changed. Each color cell called sub-pixel and one pixel consists of three sub-pixels.

The natural light **150** first reaches the first circular polarizer **120** with the same handedness as liquid crystal, for example right handed circular polarizer (RHCP) for the convenience of description. 50% left handed (LH) of incoming light is filtrated by the RHCP and other 50% right handed (RH) **151** is allowed to pass. The RH component then reaches the ChLC film in the field-induced nematic texture **114** and then passes through the ChLC film without substantially change its polarization status. The component further passes the second RHCP **130** (see light **152**) without attenuation and is reflected by an Aluminum reflector **140**, with the function of changing the light direction while maintaining the sense of polarized light. Furthermore the light **153** passes all the way through the second RHCP, ChLC film and the first RHCP without optical loss and finally emerges to the display front surface **154**. In this way, a viewer can see a full spectrum visible light.

The first and second CPs **120**, **130** are made of linear polarizers and ¼ λ retardation films with 45^0 superimposed together. In the case of infrared ChLC formulation, the ChLCD is tuned in invisible wave band. It is highly recommended to use linear polarizers instead of the circular polarizers if only the angle between the main molecular axis and the optical axis of the linear polarizer meets the light guiding requirements. The optical

"ON" state in field-induced nematic texture is an untwisted homeotropic texture regardless whether the ChLC is tuned in visible wavelength or invisible wavelength. The usage of CP herein is for dual-purpose applications: video rate display and storage type static display.

When the display is chosen a storage mode after a video speed display mode, the electric field will be withdrawn rapidly from the ChLC film in homeotropic texture and the ChLC relax into a planar texture **116**. The display becomes bistable full spectrum reflective display introduced in U.S.Patent Application, No 09/393,947, herein incorporated by reference. The out-coming light 157 then is composed of two reflections: Bragg reflection and metal reflection.

For video rate display applications the linear polarizer is totally qualified for such optical "ON" state, no matter the ChLC is tuned in visible or invisible wavelength.

As the ChLC domains addressed in a focal conic texture **115**, the display works at optical "OFF" state. The incident light **150** reaches the first CP **120** with the same handedness as the ChLC and is cut more than 50%. The rest **151** will get to the ChLC cell with focal conic texture and be depolarized by the scattering effect of the LC material. The neutral non-polarized light **155** then passing linear polarizer becomes linear polarized at the cost of at least 50% light being cut off. The linear polarized light is then reflected by the aluminum thin layer **140** and further is circularly polarized by the second CP **130** located between the ChLC cell and the metal reflector. The remaining light **156** passes the ChLC cell again and becomes depolarized light due to the focal conic scattering effect. The non-polarized remaining light reaches the first CP and half of it is lost. Finally, only small portion of total light less than 4% can reach to the front as scattered polarized light. The scattering emerged light has large viewing cone so that human eye perceives only a small portion of it. Thus the display in optical "OFF" state takes on black appearance.

The key to the motion video display is that the homeotropic metastable texture has been used for one of the optic state and the focal conic stable texture has been used for the other optic state. Both the homeotropic and the focal conic textures have fast addressing speed compared with the planar texture. The fundamental problem with the planar texture is that the relaxation from the transient planar texture to the intrinsic stable

planar texture will take about 200 microsecond. The present invention takes full advantage of cholesteric liquid crystal material: field maintained homeotropic texture as a video rate display mode and field-free planar texture as a static display mode. Both the homeotropic texture and planar texture have similar appearance to the viewer.

The black-and-white display introduces a novel way to realize real video display with relative higher contrast ratio and brightness. Prior art cholesteric display does not look bright because of most of the incoming light being absorbed by the black back coating material. By utilizing the full spectrum of incoming light, the total brightness of the display is enhanced in the video rate driving speed. One may notice the fact that the homeotropic video speed display has even better contrast ratio than that of the planar static display mode due to the higher transmittance of the homeotropic texture than that of the planar texture.

The motion video display of this invention is not limited only in the reflective display. It can also be suitable in the transmissive display or transflective display. In transmissive displays, the field-induced nematic or homeotropic area will take on dark optic "OFF" state during the video rate operation, and remain the dark state after the video rate operation. While the focal conic texture area will take on bright optical "ON" state due to the back-lit illumination. Either reflective or transmissive mode display requires that the homeotropic metastable state and the planar stable state have the same optical appearance, while the other stable state, focal conic texture has a different optical appearance.

Turning now to FIG. 2, illustrated is an electro-optical curve of a ChLCD. The ramp-up section of the curve **201** represents an optical transition from the focal conic texture to the field-induced nematic texture. The decay section **202**, meanwhile, represents another optical transition from the field-induced nematic or homeotropic texture to the focal conic texture. High level in transimittance section **203** represents the field-induced nematic texture. Note that the section **203** is not equivalent to the reflection of the planar texture depicted in the prior art because there is no relaxation process from homeotropic texture to the planar texture during the video speed display. The bottom section of the curve **204**, finally, represents the focal conic texture of the display. The low transmittance of the focal conic texture is not due to the black printing layer on the back of the display panel,

instead, is due to the depolarization effect of ChLC in focal conic texture and the multi-path absorption of the polarizers which create the optic "OFF" state.

Most importantly, this invention takes advantage of the electric controllable hesteresis, a metastability effect of the cholesteric liquid crystals. The hesteresis appears that the decay section **202** keeps parallel with the ramp-up section **201** before merge together at the two ends, a hesteretic loop. Unlike other cholesteric textures, such as planar and focal conic textures, where exist intrinsic field-free memory; the homeotropic texture has a field-maintained memory for its hesteretic loop. Generally speaking, the characteristics of the nematic to cholesteric phase relaxation constitute the metastability. As the applied voltage is decreased after the ChLC reaches its field-induced nematic phase, the relaxation may have one of the following behaviors: nonhysteretic, hysteretic, tristable, or persistent. Amount those, hysteretic, tristable and persistent are usually called the metastability of cholesteric materials. Theoretically, there is an energy barrier against the nucleation of the focal conic domains when the ChLC transforms from the homeotropic texture to the focal conic texture. It is the energy barrier that generates the hesteresis.

It was reported that the ratio of the cell thickness to the helical pitch of ChLCD, D/p, is a key factor of the hesteresis and other matastability effect (Caterin G. Lin-Hendel. *Appl. Phys. Lett.* 38,8, 1981). The hesteresis exists when the ratio, D/p> 2.5.

It was also reported by researchers in Kent State University that the polymer stabilized cholesteric texture would enhance the hesteresis loop (D.-K. YANG. *Polymer-stabilized Cholesteric Textures, Materials and Applications*, P 129).

The applicant discovers that liquid crystal material and driving method are also important to produce a suitable hesteresis. It is realized that at the same cell gap and the same reflective wavelength, some liquid crystal formulations have hesteresis and some of them do not have hesteresis, despite the fact that the ratio of the cell gap to the helical pitch meets the rule of D/p> 2.5. Such exception of not following the rule of D/p ratio is, now, under investigation. It is also realized that electric driving condition could fine-tune the hesteresis to the optimal level that is most suitable for the video rate display. Intensive study has shown that the width of hesteresis can be precisely controlled by electric signal

applied onto the same ChLCD cell. More detailed description regarding the electric modulation of the hesteresis will be disclosed separately.

There are two voltage levels physically applied onto the video rate display pixels: V_E and V_B. V_E is the erasing pulse, which drives all the pixels into homeotropic texture. V_B is the maintaining bias pulse with the amplitude, $0.1V_{CN} \leq V_B \leq 0.9\ V_{NC}$, which keeps all the pixels either in the metastable "T_{on}" , homeotropic texture or stable "T_{off}", focal conic texture (strictly, excited stable focal conic texture). However, from the FIG.2, one cannot find a decisive voltage level that determines the optical states of the display.

Turning now to FIG. 3, illustrated is a waveform driving ChLC cell into focal conic optic "OFF" state. The LC cell in its quiescent state is supposed to be an almost transparent texture **304**. It alters to scattering focal conic texture upon erasing voltage, V_E , application, and transforms at threshold voltage to a homeotropic nematic texture as a result of the field-induced phase transition. When the applied voltage is switched off from V_E to zero, a rapid relaxation will take place from the transparent nematic texture H to the initial quiescent texture. Light transmission during the rapid passage exhibits a hump **305** before it reaches minimum. The state **305** was found to be a transient planar texture, and the time interval of the transition from texture **304** to texture **305** is interpreted to be the nematic-cholesteric transition time, τ_{NC}, which is approximately within the range of 1 ms. If voltage V_B is applied after a time interval, such that $t_0 > \tau_{NC}$, an excited focal conic texture is formed, which transforms to stable focal conic texture after the voltage V_B removal. What is different from the prior art bistable storage type ChLCD is that the short pulse V_E is an erasing pulse that exerts all the display pixels in a frame at the same time, and the V_E is the only one pulse during the frame information addressing. Another fundamental difference from the prior art is that the "hole" **303** scans all over the display in a way of line-to-line rolling, starting from the first row to the final row of a display frame. Each row has only one "hole" within a frame while the rest rows are always keeping the same voltage level, V_B. Furthermore, each hole represents an optic "OFF" state.

Turning now to FIG. 4, illustrated is a waveform driving ChLC cell into field-induced nematic or homeotropic optic "ON" state. The LC cell in its quiescent state is assumed to be an almost transparent texture. It alters to homeotropic texture upon the application of

the erasing voltage, V_E . When the applied voltage is switched off from V_E to zero, a rapid relaxation from the transparent nematic texture to the cholesteric transient planar texture tends to occur without any extra energy. The present invention devises a narrow pulse **401** inserts the "hole", which breaks out the further transition from homeotropic to the cholesteric relaxation, instead, energizes the liquid crystal molecules back to the homeotropic texture. As a result, the liquid crystal molecules will remain its homeotropic texture **402** all the way to the end of the frame. The pulse width of **401** is in the range of 10 to 100 microseconds, more preferably, 20 to 60 microseconds. The height and position is also critical to the video speed driving scheme. Another fundamental difference from the prior art is that the narrow pulse scans all over the display in a way of line-to-line rolling, starting from the first row to the final row of a display frame. Each row has only one narrow pulse within a frame while the rest rows are always keeping the same voltage level, V_B. Furthermore, each narrow pulse represents an optic "ON" state. By the end of the frame addressing, if the voltage V_B is withdrawn rapidly, the ChLCD will relax to the stable planar texture via the transient planar relaxation curve **403**. Such relaxation time normally is in the range of 20 milliseconds to 20 seconds depending on variety of parameters. Obviously, such relaxation should be avoided in the fast video rate display, but it is useful in a static display for its zero-field permanent memory effect. Compared with the section of 402 and 403, one may find out that both the motion video display and the motionless storage display have almost the same optical bright appearance.

Turning now to the FIG. 5, illustrated is a waveform and its optical response curve of "m" line addressing. The first line's addressing has already depicted in FIG. 3 and FIG.4 separately. Assuming that a line-at-a-time addressing from the first line to the "m-1" line has already passed when the scanning address comes to the "m" line. The waveform section **501** at voltage level, V_B, ensures the liquid crystal molecules in the homeotropic texture **504** after the erasing pulse V_E. And the waveform section **502** ensures to maintain the optical states **506, 508** having been addressed in the "m" line. The "hole" **503** positioned at "m" line activates all the programmed pixels in the line relaxing to focal conic texture through a transient planar texture **505**. In other words, the "hole" at the line drives all the related pixels to the optic "OFF" state. At the same time, a narrow pulse **507** planted in the "hole" **503** will bridge all the programmed pixels in the line,

maintaining their homeotropic texture **508**. In other words, the narrow pulse at the line drives all the related pixels to the optic "ON" state.

By the end of the frame addressing, if the voltage V_B is withdrawn rapidly, the ChLCD pixels, pre-set in the focal conic texture, will maintain its optical "OFF" state. And the pixels, pre-set in the homeotropic texture, will relax to the stable planar texture via the transient planar relaxation curve **509**. Such relaxation time normally is in the range of 20 milliseconds to 20 seconds depending on variety of parameters. Obviously, such relaxation should be avoided in the fast video rate display but it is useful in a static display for its zero-field permanent memory effect.

More logically, the "hole" **503** is termed **Data "0"** signal; and the narrow pulse **507** is termed **Data "1"** signal.

Data "1" signal can be further modulated to achieve a mixture of homeotropic texture **508** and focal conic texture **506** within one pixel so as to obtain a gray-scale in the video rate display environment. Herein the modulation means that the pulse height can be modulated according to the data signal.

The key to the waveform of the motion video display is that after the whole frame erasing pulse, there is only one hole per line per frame, which is the time window of recording. However, each row's addressing time is not determined by the width of the "hole". Instead, it is determined by the width of the narrow pulse, in other words, the width of **Data "1"** signal.

Turning now to the FIG. 6, illustrated is a waveform and its optical response curve of inter-frame addressing. During the course of the last line's addressing in previous frame, **Data "1"** pulse **601** maintains the pixel in the optic "ON" state and **Data "0" 603** activates the pixels from homeotropic texture **604** to the focal conic optic "OFF" state **606** via the transient planar texture **605**. A minimum display time T_{FD} is necessary to ensure display's contrast ratio in the last portion of the display panel. Thus an optimal duration of focal conic optic "OFF" state **606** is essential to the driving means. After a consecutive line-to-line addressing in the previous frame, an erasing pulse of a new frame **607** is applied onto all the pixels of the display panel. It erases all the information addressed in the previous frame, no matter whether the previous optic state is focal conic texture **606** or homeotropic texture **602**. Before the falling edge of the erasing pulse, all

the pixels will be energized to field-induced nematic phase or homeotropic texture. The basic function of **607** is the same as the first erasing pulse **301**. However, The erasing pulse width of the new frame is much shorter than the first erasing pulse **301**. For example, the new erasing pulse can be devised in the range of 1-5 milliseconds. Thus, a viewer in the continuous video rate display will not discern such a short erasing period.

The short erasing pulse attributes to the following reasons. First, the previous data in the optic "on" state have already been set in the homeotropic texture, only a little more energy is necessary to increase the order parameter of the field-induced nematic configuration. Secondly, the previous data in the optic "off" state are, as a matter of fact, an excited focal conic texture due to the constant activation of V_B. In such excited focal conic texture, the fan-shaped domains vibrate relatively with each other resulting in a stronger scattering to the incoming light and higher depolarization efficiency than that of the quiescent focal conic texture. Therefore, a short erasing pulse will be enough to drive the excited focal conic texture to the field-induced nematic texture.

The functions of the "hole" **608** or **Data "0"** and narrow pulse **611** or **Data "1"** are similar to **603** and **601** in terms of addressing the ChLCD to the focal conic texture **610** and homeotropic texture **612** respectively.

One may notice that during the continuous inter-frame addressing, there is no any relaxation from field-induced nematic to the planar texture happened, so that a motion video display can be achieved.

Turning now to the FIG. 7, illustrated is a video speed driving scheme. The erasing pulse **701** synthesized by out-phase waveform **702** and **703** from column and row driver is applied all the pixels at the beginning of the frame addressing. Column driver also generates a positive **Data "1"** pulse **704** with narrow pulse-width and high signal frequency. Row driver, at the same time, generates a negative pulse **705** that shifted from the first row to the last row of the frame, subsequent to the frame erasing pulse. The interval between the two negative pulses **706** is equal to the **Data "1"** pulse-width $\Delta\tau$. The **Data "1"** waveform **707**, and the **Data "0"** waveform **708**, synthesized by the column driver and the row driver, are applied onto the display pixels from L_1 to L_N consequently. The **Data"1"** narrow pulse and **Data "0"** hole, as a part of the waveform,

are also shifted from one line to another with an interval of the **Data "1"** pulse-width. The frame addressing time is:

$$T_{FA} = T_E + \tau_{NC} + n\Delta\tau$$

Assuming the erasing pulse, $T_E = 2$ ms, Scanning pulse, $\tau_{NC} = 1$ ms, Data "1" pulse-width, $\Delta\tau = 0.03$ ms and the row number, $n = 500$, then

$$T_{FA} = 2 + 1 + 15 = 18 \text{ ms.}$$

Assuming, again, the display time per frame,

$$T_{FD} = 15 \text{ ms,}$$

Then the total frame time is

$$T_F = T_{FA} + T_{FD} = 33 \text{ ms.}$$

There will be 30 frames information displayed per second. Thus achieves a normal VGA type video rate display.

One may notice that the display time, T_{FD}, prolongs the frame time. Furthermore, it directly impacts the feasibility of video speed display with very high resolution. To achieve a video rate large panel display, for instance, SVGA (800x600), XGA (1024x768) etc., the display time, T_{FD}, should be further reduced or even eliminated. Dual-scan, with two column drivers attached each side of the column electrode respectively and the electrode, along the column direction, broken into half-and-half at the center of the display, is a good solution. An original frame, now, is divided into two sub-frames. The two sub-frames are capable of working alternatively. For example, one sub-frame that has just finished addressing will subject to the display mode, while the other one is carrying out erasing and addressing process. As far as the whole display panel is concerned, there is always constantly scanning. Therefore, the frame time will be

$$T_F = T_{FA} = T_E + \tau_{NC} + n\Delta\tau$$

Take a 1024x768 display for example, assuming the erasing pulse $T_E = 2$ ms, Scanning pulse $\tau_{NC} = 1$ ms, Data "1" pulse-width $\Delta\tau = 0.04$ ms and the row number $n = 768$, then

$$T_F = 2 + 1 + 30.7 = 33.7 \text{ ms.}$$

There will be 30 frames information displayed per second on a 1024x768 LCD panel.

Though the erasing high pulse is an AC waveform, the addressing pulse belongs to DC waveform within one frame. To obtain a DC-free driving voltage on each pixel, the

polarity of the addressing pulse needs to be switched over every individual frame. A frame high/low signal from the LCD controller enables those functions. By so doing, there will be no DC charge accumulated in the video rate display.

The above-mentioned driving means possesses the following advantages:

1. Simplicity of waveform

The erasing and addressing pulses have relatively simple waveform and less voltage levels. There are four voltage levels altogether in the display drive scheme, which allows utilizing the commercially available "polar" CMOS driver, for example, STN driver.

2. DC-free erasing pulse

Since the erasing pulse is a high voltage pulse, any possible DC component will cause a huge negative impact on the display's working condition and display's longevity. The designed erasing pulse is synthesized by out-phase waveforms from column and row driver, so that there is no any DC component at any time.

3. Simplicity in driving logic design

Data signal in the present invention becomes a standard binary system: Column signal **Data "1"** is a narrow pulse and column signal **Data "0"** is actually a zero pulse. Scanning row signal, on the other hand, becomes a negative pulse shifting from the first line to the last line of a frame.

Turning now to the FIG. 8, illustrated is a partial addressed video speed driving scheme. What is different from FIG. 7 is that the driving scheme allows coexistence of information displaying and information erasing in the same frame. The row driver becomes waveform synthesizer which generates both the erasing pulse and part of the addressing pulse. The column driver only supplies **Data "1"** narrow pulse.

Compared with the waveform introduced in FIG. 7, the row driver has heavier power load because it have to take care of both erasing pulse and most part of addressing pulse. At least one thing is certain that a conventional STN driver will be able to qualify as the waveform generator. Since STN driver can generate four-level voltages that totally satisfy with the requirement of the video rate row driver in the present invention. However, the frame logic control signal should be enabled to switch the polarity of the

waveform from positive to negative every frame, so as to eliminate the DC charge in liquid crystal material.

The column driver, on the other hands, is no longer a contributor of the erasing pulse and specialized for the data input. The skilled of the art allows to utilize a TFT driver as well as the STN driver. TFT driver is famous for the pulse-height-modulation for a gray scale display mode. In a motion video display, the data signal, before getting into the TFT driver circuit, has been converted from R.G.B analog video signal to 8 gray scale digital signal by a LCD video interface controller (LVIC). By using the TFT driver, originally only for the active video display, the present invention realizes a passive cholesteric motion video display with multi gray scale level. Since the TFT driver can modulate the pulse-height of **Data "1"**, consequently it will induce a mixture of cholesteric focal conic texture and field-induce nematic texture in the same pixel, a principle of the gray scale display. Therefore, one of the most important functions of the driving waveform is that it is the best driving method for the cholesteric video-rate-gray-scale display.

The other very important function of the driving scheme is partially driving: one portion of the display is under erasing and addressing and the other portion of it is displaying. The frame rate will be increased as the display time no longer being a part of the frame time.

The above-mentioned display mode (FIG. 1) and driving means (FIG. 2-8) have been disclosed, in details, a motion video cholesteric display which is the best candidate of a true multimedia e-book. For example, many children's e-books have now been adapted to a multimedia "interactive" environment. "Interacting" with a multimedia e-book may be as simple as clicking objects on the display's screen to see what they do. Clicking a character from the book might make it jump around the screen. Clicking a window might make it open and then slam shut. Clicking a cloud in the sky might make erupt from the speakers. To be a true multimedia e-book, of course, it must also contain sound as well as picture and animations. On the other hand, the multimedia e-book must be a "green" product, save energy and human friendly. Cholesteric display is obviously superior to the currently TFT AM LCD and STN LCD in such applications.